**DEFENSE ADVANCED RESEARCH PROJECTS AGENCY**
***Submission of Proposals***

DARPA's charter is to help maintain U.S. technological superiority over, and to prevent technological surprise by, its potential adversaries. Thus, the DARPA goal is to pursue as many highly imaginative and innovative research ideas and concepts with potential military and dual-use applicability as the budget and other factors will allow.

DARPA has identified technical topics to which small businesses may respond in the first fiscal year (FY) 2003 solicitation (FY 2003.1). Please note that these topics are UNCLASSIFIED and only UNCLASSIFIED proposals will be entertained. Although the topics are unclassified, the subject matter may be considered to be a "critical technology". If you plan to employ NON-U.S. Citizens in the performance of a DARPA SBIR contract, please inform the Contracting Officer who is negotiating your contract. These are the only topics for which proposals will be accepted at this time. A list of the topics currently eligible for proposal submission is included followed by full topic descriptions. The topics originated from DARPA technical program managers and are directly linked to their core research and development programs.

**Coversheet and Company Commercialization Report must be entered into the DoD electronic database in order for the proposal to be eligible for evaluation**. Please note that **1 original and 4 copies** of each proposal must be mailed or hand-carried. DARPA will **not** accept proposal submissions by facsimile (fax). A checklist has been prepared to assist small business activities in responding to DARPA topics. Please use this checklist prior to mailing or hand-carrying your proposal(s) to DARPA. Do not include the checklist with your proposal.

DARPA Phase I awards will be Firm Fixed Price contracts.

Phase I proposals **shall not exceed $99,000,** and may range from 6 to 8 months in duration. Phase I contracts can ONLY be extended if the DARPA Technical Point of Contact wants to "gap" fund the effort to keep a company working while a Phase II is being generated.

DARPA Phase II proposals must be invited by the respective Phase I DARPA Program Manager (with the exception of Fast Track Phase II proposals – see Section 4.5 of this solicitation). DARPA Phase II proposals must be structured as follows: the first 10-12 months (base effort) should be approximately $375,000; the second 10-12 months of incremental funding should also be approximately $375,000. The entire Phase II effort should generally not exceed $750,000.

It is expected that a majority of the Phase II contracts will be Cost Plus Fixed Fee. However, DARPA may choose to award a Firm Fixed Price Contract or an Other Transaction, on a case-by-case basis.

Prior to receiving a contract award, the small business **MUST** be registered in the Central Contractor Registration (CCR) Program. You may obtain registration information by calling 1-888-227-2423 or Internet: http://www.ccr.gov.

The responsibility for implementing DARPA's SBIR Program rests in the Contracts Management Office. The DARPA SBIR Program Manager is Ms. Connie Jacobs. DARPA invites the small business community to send proposals directly to DARPA at the following address:

**DARPA/CMO/SBIR**
**Attention: Ms. Connie Jacobs**
**3701 North Fairfax Drive**
**Arlington, VA 22203-1714**
**(703) 526-4170**
**Home Page http://www.darpa.mil**

SBIR proposals will be processed by the DARPA Contracts Management Office and distributed to the appropriate technical office for evaluation and action.

DARPA selects proposals for funding based on technical merit and the evaluation criteria contained in this solicitation document. DARPA gives evaluation criterion a., "The soundness and technical merit of the proposed approach and its incremental progress toward topic or subtopic solution" (refer to section 4.2 Evaluation Criteria - Phase I), twice the weight of the other two evaluation criteria. **TRANSITION OF THE PROPOSED EFFORT IS VERY, VERY IMPORTANT. THE SMALL BUSINESS SHOULD INCLUDE THEIR TRANSITION VISION IN THEIR COMMERCIALIZATION STRATEGY. THE SMALL BUSINESS MUST UNDERSTAND THE END USE OF THEIR EFFORT AND THE END USER, i.e., ARMY, NAVY, AF, SOCOM, ETC.**

As funding is limited, DARPA reserves the right to select and fund only those proposals considered to be superior in overall technical quality and highly relevant to the DARPA mission. As a result, DARPA may fund more than one proposal in a specific topic area if the technical quality of the proposal(s) is deemed superior, or it may not fund any proposals in a topic area. Each proposal submitted to DARPA must have a topic number and must be responsive to only one topic.

Cost proposals will be considered to be binding for 180 days from closing date of solicitation.

**Successful offerors will be expected to begin work no later than 30 days after contract award.**

For planning purposes, the contract award process is normally completed within 45 to 60 days from issuance of the selection notification letter to Phase I offerors.

The DoD SBIR Program has implemented a Fast Track process for SBIR projects that attract matching cash from an outside investor for the Phase II SBIR effort, as well as for the interim effort between Phases I and II. Refer to Section 4.5 for Fast Track instructions. DARPA encourages Fast Track Applications ANYTIME during the 6th month of the Phase I effort. The Fast Track Phase II proposal must be submitted no later than the last business day in the 7$^{th}$ month of the effort. **Technical dialogues with DARPA Program Managers are encouraged to ensure research continuity.** If a Phase II contract is awarded under the Fast Track program, the amount of the interim funding will be deducted from the Phase II award amount. It is expected that interim funding will generally not exceed $40,000.

To encourage the transition of SBIR research into DoD Systems, DARPA has implemented a Phase II Enhancement policy. Under this policy DARPA will provide a Phase II company with additional Phase II SBIR funding, not to exceed $200K, if a DARPA Program Manager can match the additional SBIR funds with DARPA core-mission funds or the company can match the money with funds from private investors; or at the discretion of the DARPA Program Manager. DARPA will generally provide the additional Phase II funds by modifying the Phase II contract.

**DARPA FY2003.1 Phase I SBIR**
***Checklist***

Page Numbering

Number all pages of your proposal consecutively ______
Total for each proposal is 25 pages inclusive of cost proposal and resumes
Beyond the 25 page limit do not send appendices, attachments and/or additional references
Company Commercialization Report **IS NOT** included in the page count

Proposal Format

b. Cover Sheet **MUST** be submitted electronically (identify topic number) ______

c. Identification and Significance of Problem or Opportunity ______

d. Phase I Technical Objectives ______

e. Phase I Work Plan ______

f. Related Work ______

g. Relationship with Future Research and/or Development ______

h. Commercialization Strategy ______

i. Key Personnel, Resumes ______

j. Facilities/Equipment ______

k. Consultants ______

l. Prior, Current, or Pending Support ______

m. Cost Proposal. Ensure your cost proposal is signed. ______

n. Company Commercialization Report **MUST** be registered electronically and a hardcopy submitted with your proposal (register at http://www.dodsbir.net/submission/) ______

Bindings

Staple proposals in upper left-hand corner ______
**<u>DO NOT</u>** use a cover
**<u>DO NOT</u>** use special bindings

Submission Requirement for Each Proposal

Original proposal ( including signed Coversheet) ______
Four photocopies of original proposal (including signed Coversheet) ______
Company Commercialization Report ______

**DARPA 03.1 SBIR TOPICS**

| | |
|---|---|
| SB031-001 | Oxynitrides for High Speed Missile Applications |
| SB031-002 | Investigation of Thermal Effects in Crossover-Free Fiber Optic Gyroscope Micro-Sensor Coils |
| SB031-003 | Accelerated Monte Carlo Methods for Simulation of Rarefied Material Dynamics |
| SB031-004 | Sub-Wavelength Lithography Employing Phase Masks |
| SB031-005 | Cost-Effective Production of Piezoelectric Single Crystals |
| SB031-006 | Virtual Soldier Scan |
| SB031-007 | Alternative Transducers for Handheld Automatic Speech Recognition in Military Environments |
| SB031-008 | Cluster-Based Repositories and Analysis |
| SB031-009 | Modeling Asymmetric Threats to Critical Infrastructure |
| SB031-010 | Wireless Near-Infrared Devices for Neural Monitoring in Operational Environments |
| SB031-011 | Personnel Monitoring for Assessment and Management of Cognitive Workload |
| SB031-012 | Next-Generation, Unifying Architecture for Intelligent Agents |
| SB031-013 | Distributed Tracking with Networked, Dynamically Relocatable Sensors |
| SB031-014 | Novel Sensors and Signal Processing for Detecting and Classifying Combatants Operating in Urbanized Terrain |
| SB031-015 | Motion Based Video ATR |
| SB031-016 | Design of Nano-Photonics Devices and Systems |
| SB031-017 | Miniaturized Scanning Electron Microscope |
| SB031-018 | Noise Tolerant Nanoelectronics |
| SB031-019 | Distributed Electronics |
| SB031-020 | Lithographically Scribed Planar Holographic Devices |
| SB031-021 | Sea Glider Transport Vehicle |
| SB031-022 | High Resolution Local Sea Surface Mapper |
| SB031-023 | Short-Range Ultra-Low-Cost Anti-Submarine Sensors |
| SB031-024 | Rapid Design & Development of Behaviors for Autonomous Vehicles |
| SB031-025 | Anti-Icing Technology for Unmanned Rotorcraft |

## SUBJECT/WORD INDEX TO THE DARPA FY2003.1 TOPICS

# DARPA 03.1 TOPIC DESCRIPTIONS

SB031-001 TITLE: Oxynitrides for High Speed Missile Applications

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The objective of this program is to demonstrate improvement in performance of an oxynitride composition as a bulk infrared (IR) transparency material and as a protective antireflective coating. The aim is to increase the optical transmission from the visible beyond the midwave to 8 micrometers, to provide increased hardness and strength of approximately 2x that of sapphire, and with increases also in thermal conductivity and thermal shock resistance.

DESCRIPTION: Oxynitrides have demonstrated versatility of properties and capability for affordable bulk processing as optical/millimeter-wave transparency materials. Potential has been shown for increased resistance to thermal shock, greater thermal conductivity, increased hardness, greater strength and broader infrared optical transmission waveband. These potential performance improvements are needed for IR transparencies in the thermal environments of high-speed missiles and in harsh environments where dust erosion is a major concern. These materials will affordably increase the performance window for high-speed missiles and provide greater flexibility in the overall seeker system design to include additional wavelength insertion in the overall image resolution. Missile domes and windows must also be resistant to rain and dust erosion during captive carry prior to use and during actual missile flight. Increased strength will enable missile domes and windows to survive these harsh environments as well as withstand the thermal shock associated with high-speed flight. In addition, potential also exists with the oxynitrides to greatly enhance ballistic performance for transparent armor applications.

PHASE I: This effort is to study the feasibility of the proposed approach to meeting the goals set forth in the objective, i.e., producing an oxynitride composition that extends the transmission window and increases the strength. The approach will include high purity synthesis/processing to bulk samples of sufficient size for measurements of hardness, thermal conductivity, impact resistance, dielectric properties and optical transmission/scatter at both ambient and high temperatures (>1300K). The sample batch sizes should be sufficient to generate 1” x 1” blanks for independent verification of materials properties. These samples shall be provided to the Government. A sufficient number of processing runs (at least 3) will be made to demonstrate feasible consistency of properties. The approach should demonstrate significant progress towards a 2x improvement in hardness and strength over sapphire and transparency from the visible to 8 micrometers. The approach should also demonstrate a clear path to achieving the goal of a 2x improvement in hardness and strength over sapphire.

PHASE II: Development of the process developed in Phase I with the demonstration of an optically transparent material from the visible to 8 micrometers, minimum 80% transmission, 2x improvement in hardness and strength over sapphire and scalability to 6" diameter domes and 12" x 12" windows. Sufficient runs shall be made to demonstrate consistency in the process and samples provided to the Government for independent verification of materials properties. The process should be capable of achieving these performance metrics in production quantities.

PHASE III DUAL USE APPLICATIONS: Candidate dual use applications include stronger, lighter, more durable windows for civilian aircraft, durable windows for supermarket scanners, and windows for deep sea submersibles.

REFERENCES:
1. Harris, Dan, "Material for Infrared Windows and Domes," ISBN 0-8194-3482-5, SPIE Press, 1999.

KEYWORDS: Oxynitrides, IR Materials, Transparent Armor

SB031-002 TITLE: Investigation of Thermal Effects in Crossover-Free Fiber Optic Gyroscope Micro-Sensor Coils

TECHNOLOGY AREAS: Air Platform, Materials/Processes, Space Platforms, Weapons

OBJECTIVE: The objective of this effort is to investigate the effects of thermal gradients in single mode fiber micro-sensor coils for use in fiber optic gyroscopes (FOG). The goal is to compare the performance of crossover-free micro-sensor coils with conventional-wound micro-sensor coils and improve the performance of the single mode micro-sensor coils through the use of advanced materials and fabrication techniques. The use of single mode fiber in micro-sensor coils of this type should result in improved coil performance, improved sensor repeatability, and reduced cost.

DESCRIPTION: The crossover-free winding scheme utilized for single mode micro-sensor coils should: 1) provide polarization control through stress-induced birefringence, 2) eliminate fiber crossovers, and 3) address thermal stability in both the radial and axial winding directions. Sensor coils fabricated in this manner should offer improved performance, increased lifetime, and improved reliability. Coil pack imperfections caused by voids created during the winding process affect the overall thermal performance of the micro-sensor coil. Reduction of the number and severity of these voids should result in smaller thermal gradients, thereby improving coil-to-coil performance.

PHASE I: The approach will include performing birefringence measurements on candidate single mode fiber optic cables to identify the fibers that are best suited for the crossover-free micro-sensor coil. Analysis and research of suitable advanced materials and processes of the constituent parts and the fabrication technique to ensure optimal sensor performance and implementation shall be addressed.

PHASE II: This phase will include the winding of several micro-sensor coils according to the conventional quadrupolar winding
method, and the crossover-free, thermally stable coil winding method. A direct comparison of the thermal effects for each method must be made. This phase will also include the investigation of thermal effects on the performance of the subject fiber sensor coils when fabricated using an automated system. The performance of the previously fabricated coils shall be evaluated against the coils fabricated with the automated system. Research into methods to further improve the performance and manufacturability of the automatically wound coils will be accomplished.

Phase III Dual-Use Applications: The development of advanced micro-sensor coils as described here will result in high-performance, low-cost, inertial systems capable of being implemented into both military and commercial applications. Automated manufacture of these coils will result in a high degree of sensor accuracy and repeatability as well as providing the capability for efficient manufacturing. Commercial applications in the aerospace and automotive industries have great potential as well as applications in commercial optics, image platform stabilization and entertainment.

KEYWORDS: Fiber Optic Gyroscope, Micro-Sensor Coil, Thermal Effects, Materials.

SB031-003 TITLE: <u>Accelerated Monte Carlo Methods for Simulation of Rarefied Material Dynamics</u>

TECHNOLOGY AREAS: Information Systems, Materials/Processes

OBJECTIVE: This topic will identify and develop innovative ideas, concepts, and methodologies for acceleration of computational methods for rarefied gas dynamics.

DESCRIPTION: Monte Carlo simulation of rarefied material dynamics is a required step in many computational methods for problems involving gases and vapors having low-density regions and boundary layers. Examples include: material fabrication, such as chemical vapor deposition (CVD) and sputtering space-based lasers upper-atmospheric flight nano- and micro-fluid flows, such as disk read-write heads. Since the 1970s, the Direct Simulation Monte Carlo (DSMC) method has been the principal computational method for rarefied flows. DSMC is robust and effective for many applications, but it becomes computationally expensive and frequently intractable for problems involving small Knudsen number (i.e., small meaning free path) for which a continuum fluid-dynamic description is approximately valid. Small Knudsen number flows are prevalent in important applications, such as those listed above, since they occur wherever there is a transition from a continuum flow to a rarefied flow. Thus DSMC is computationally unattractive in these domains. This topic will address the development and demonstration, in the context of a suitable application domain, of rigorous simulation methods that incorporate fluid information to accelerate Monte Carlo simulation for steady and unsteady rarefied flows with small Knudsen number. Techniques that could be used for this purpose include implicit treatment of the collision process, variance reduction using fluid information and hybrid approaches that combine continuum and rarefied descriptions of the flow.

PHASE I: Perform a feasibility study in which viable candidate approaches for acceleration or Monte Carlo methods for simulation of rarefied flows are identified and a recommendation of the best candidate methodology for further development is formulated. The feasibility assessment should culminate with the outline of a plan for further development in the context of a suitable application domain and an assessment of the feasibility of the plan, including risks and potential payoffs in both defense and civilian applications.

PHASE II: Implement prototype simulation software incorporating the Monte Carlo methodology developed. Validate and demonstrate the performance of the capabilities developed on representative focus problems from the selected application domain.

PHASE III DUAL USE APPLICATIONS: The simulation technology developed under this Topic is expected to enable substantially larger and more accurate simulation of rarefied gas dynamics, a critical component in computational design methods in numerous defense and civilian commercial applications. A particularly prevalent dual-use application arena in which virtual design is enabled by simulations of this kind is material fabrication, including electronic material processes such as chemical-vapor deposition and sputtering. Other important application areas of particular value in defense are modeling and prediction of space-based lasers performance and modeling of physical phenomena entailed in upper-atmospheric flight.

REFERENCES:
1. Oran, E.S., Oh, C.K., and Cybyk, B.Z., "Direct Simulation Monte Carlo: Recent Advances and Applications," Annual Review of Fluid Mechanics, 1998, Vol. 30, Issue 1, p. 403.
2. Pareschi, L. and Caflisch, R.E., "An implicit Monte Carlo method for rarefied gas dynamics I: The space homogeneous case," J. Comp. Phys., 1999, Vol. 154, p. 90.
3. Gallis, M. A., Torczynski, J. R., and Rader, D. J., "An approach for simulating the transport of spherical particles in a rarefied gas flow via the direct simulation Monte Carlo method," Physics of Fluids, Nov. 2001, Vol. 13, Issue 11, p. 3482.
4. Hadjiconstantinou, N.G. and Garcia, A.L., "Molecular simulations of sound wave propagation in simple gases," Physics of Fluids, Apr. 2001, Vol. 13, Issue 4, p.1040.
5. Hadjiconstantinou, N.G., "Analysis of discretization in the direct simulation Monte Carlo," Physics of Fluids, Oct. 2000, Vol. 12, Issue 10, p. 2634.
6. Mizuseki, H., Jin, Y., Kawazoe, Y., and Wille, L.T., "Growth processes of magnetic clusters studied by direct simulation Monte Carlo method," Journal of Applied Physics, May 2000, Vol. 87, Issue 9, p. 6561.
7. Dogra, V.K. and Collins, R.J., "Modeling of spacecraft rarefied environments using a proposed surface model," AIAA Journal, Apr. 1999, Vol. 37, Issue 4, p. 443.

KEYWORDS: Direct Simulation Monte Carlo; Gas Dynamics

SB031-004 TITLE: <u>Sub-Wavelength Lithography Employing Phase Masks</u>

TECHNOLOGY AREAS: Information Systems, Materials/Processes, Sensors, Electronics, Battlespace, Weapons

OBJECTIVE: The objective of the project is to develop well posed mathematical techniques that enable sub-wavelength lithography (feature size smaller than the wavelength) of integrated circuits by applying inverse methods to design phase masks such that device density increases while maintaining adequate yield.

DESCRIPTION: In optical lithography, it has become clear that the Rayleigh resolution criterion needs to be modified to account for the great progress in our understanding of the photolithographic process. Very narrow lines, much less than an optical wavelength can be printed. With the introduction of phase masks, and the use of interference effects, optical lithography can continue to produce circuits of ever increasing density. High levels of performance can already be achieved by one-photon lithography, with the proper design of phase masks, and other improvements in the optical system. The optimized design of phase masks is a category of mathematical inverse problems. Given a desired image (circuit), what is the optimum mask design that would create that image? There is good reason to expect that a solution of the inverse problem would exist, and in general the solution will not be unique due to the presence of a null space. In addition, the lithographic process itself will likely support additional solutions that satisfy other constraints, such as image robustness under depth of field variations, under exposure variations, misalignment variations, etc. With the introduction of phase masks by Levenson, a new kind of lithographic philosophy presented itself. Ordinary masks are a direct photographic representation of the desired circuit patterns. With phase masks however, the mask patterns do not necessarily have a direct match to the desired circuit image, although the general pattern maybe directly visible in the phase mask. As the sophistication of phase mask design grows, and as the additional design degrees of freedom are employed, phase masks will appear more and more like holograms. They will be very complex, and it may not be possible to discern the desired image directly in the mask. Nevertheless they will print high-resolution circuit patterns, correctly and robustly, as desired. The task then is to find a systematic methodology to design the phase mask, and to solve the inverse problem for this application.

PHASE I: Feasibility study of a robust mathematical approach that enables design of phase masks supporting sub-wavelength feature sizes; preliminary implementation of the mathematical algorithm; preliminary design of a circuit; and simulation of the lithography (forward problem).

PHASE II: Implementation of the algorithm in a robust validated code, design of an integrated circuit, and fabrication of the circuit demonstrating that the desired circuit has been lithographically formed.

PHASE III DUAL USE APPLICATIONS: Integrated circuits are a ubiquitous technology that is at the heart of all DoD and commercial sensors, computers, and modern electronic devices. The proposed technology to be developed under this SBIR would enable device densities to increase without major changes to existing fabrication facilities. A technology such as this would enable higher density of devices, and potentially higher yields decreasing costs to both DoD and the civilian sector. This technology will change the way the chip industry does business.

REFERENCES:
1. Levenson, M.D.; Viswanathan, N.S.; Simpson, R.A. Improving resolution in photolithography with a phase-shifting mask. IEEE Transactions on Electron Devices, vol.ED-29, (no.12), Dec. 1982. p.1828-36.

KEYWORDS: Lithography, Inverse Problems, Phase Mask

SB031-005 TITLE: Cost-Effective Production of Piezoelectric Single Crystals

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Devise and demonstrate cost-effective methods to fabricate single crystal relaxor piezoelectrics (having the extraordinary electromechanical properties of high coupling: 90-95 %, and high strain: ~ 1 %) in the appropriate form (bulk, multilayer, fibers, thin films, etc.) for producing practical devices for defense and civilian applications.

DESCRIPTION: Near the onset of 1997 came the discovery that single crystals of certain relaxor ferroelectric materials (lead magnesium niobate – lead titanate, and lead zinc niobate – lead titanate) exhibit extraordinary piezoelectric properties, namely, strains exceeding 1%, and electromechanical coupling exceeding 90% (compared to 0.1% and 70-75 %, respectively, in state-of-the-art piezoceramics). Concerted efforts to grow these materials in a variety of forms (bulk, multilayer, fibers, thin films, etc.) now yield materials in quantities, and at a price, suitable for device prototyping. Efforts to demonstrate prototype device performance are underway. This topic aims to devise materials synthesis/growth technology that will allow the rapid transition of these materials from device technology demonstrations into the production of practical devices for defense and civilian markets. While the materials technology being developed should target an application arena (for example, to define the form—bulk, fiber, film, multilayer—in which the piezocrystal is produced), that application is only incidental to the work performed. Nevertheless, clearly establishing a linkage between the proposed materials development to a targeted application of importance to the Army, Navy, or Air Force would provide a big plus.

PHASE I: Demonstrate the feasibility of an innovative materials synthesis/growth methodology that substantially lowers the cost of relaxor piezocrystal production (bulk, fiber, film, multilayer, etc.). The final report must present an analysis of the manufacturing cost (capitalization, labor, materials) in a production, not development, mode.

PHASE II: Implement the innovative piezocrystal synthesis/growth technology and demonstrate "zero batch" production in a form suitable for some candidate application; validate cost projections in detail. Survey potential manufacturing markets and develop a pricing structure for production at various annual rates.

PHASE III DUAL USE APPLICATIONS: Produce materials for applications in the defense sector ranging from Navy sonar, through Army rotorblade control, to Air Force airfoil shape control. In the civilian sector, applications target for this materials technology include medical ultrasonic diagnostics and therapy, active machine tool control, and vibration suppression in HVAC systems.

REFERENCES:
1. S.E. Park and T.R. Shrout, "Ultrahigh Strain and Piezoelectric Behavior in Relaxor based Ferroelectric Single Crystals, " J. Appl. Phys., 82[4], 1804-1881 (1997).
2. S.E. Park and T.R. Shrout, " Characteristics of Relaxor-Based Piezoelectric Single Crystals for Ultrasonic Transducers," IEEE Trans. On Ultrasonic Ferroelectrics and Frequency Control, Vol. 44, No. 5, 1140-1147 (1997).

KEYWORDS: Materials Synthesis/Growth Technology, Solid State Crystal Growth, Single Crystals, Piezoelectrics, Relaxor Ferroelectrics, Lead Magnesium Niobate –Lead Titanate, and Lead Zinc Niobate – Lead Titanate, Electromechanical Sensors and Actuators, Smart Materials, Vibration Control, Shape Control, Acoustic Transducers, SONAR

SB031-006 TITLE: Virtual Soldier Scan

TECHNOLOGY AREAS: Information Systems, Materials/Processes, Biomedical, Human Systems

OBJECTIVE: The objective of this research is to develop an intelligent multi-modal scanning technology which can simultaneously acquire anatomic (Computer Tomography, Magnetic Resonance Imaging or Electron Beam Tomography, etc) and functional (Positron Emitting Tomography, Single-Photon Computing Tomography, etc) data using the same scanner and detector, thereby providing instant virtual representation of the soldier with multiple modes perfectly segmented and registered. The long-term goal is to have this total soldier scanner at every forward hospital, which is receiving casualties for triage.

DESCRIPTION: Today there are multiple types of scanners, each providing a particular type of dataset (anatomic, physiologic, functional, molecular, etc), each taking time to produce and which are extremely difficult to integrate through data fusion. DoD must have a multiple mode scanner, which collects many different modalities simultaneously, and within seconds to a few minutes can produce a full 3-D image of the soldier. This specific solicitation deals with developing the physical scanner (data acquisition).

PHASE I: This phase is expected to produce an initial evaluation of candidate materials for innovative detectors, a report of material performance, and a design study for the device. This is a feasibility study for detector materials, with cesium compounds being among the most likely candidates. Candidate samples will be evaluated for critical parameters (resolution, brightness, contrast, etc) in each of the modes (CT, PET and SPECT). A design study will be performed for the detector with the multiple acquisition modalities and the integrated electronic readout array for the different modalities.

PHASE II: The deliverable is a prototype detector, which can acquire a multi-modal image of the human body. This phase will fabricate a full size breadboard prototype detector plate (front-end) with incorporated electronics backplate (back-end). The critical issues will include scalability, generalizability, durability, robustness and address concerns for ergonomics and human interface technology. Complete documentation will be collected on materials properties, specifications, interface compatibilities, etc. Initial alpha prototype software will be written for the purpose of demonstration of the feasibility of 3-D rendering of each of the modalities. Testing will be performed upon phantoms to illustrate the multi-modality capabilities of the detector and the accuracy of the data fusion. This will not be a clinically usable system, rather a set of devices that have been integrated to demonstrate functionality.

PHASE III DUAL USE APPLICATIONS: One of the critical needs for wounded soldiers is an instant, accurate, complete assessment of their casualty status. This is performed by physical exam, and then sending the casualty to various radiology departments for multiple types of x-rays and scans. Not only would the candidate scan apply to casualties from the battlefield, but also provide the same capability for trauma evaluation in every emergency room across the world. Phase III will address moving from breadboard prototype to fully integrated beta-prototype, complete with electronic packaging and software capabilities of full 3-D rendering of all modalities and with accurate segmentation, data fusion and registration. There will also be a design of manufacturing and assembly requirements. Testing will be of animal models and then clinical trials.

REFERENCES:
1. Scheiber C, Giakos G. "Medical applications of CdTe and CdZnTe detectors", Nuclear Instruments & Methods in Physics Research, A 458(2001) 12-15, Elsevier Science B.V.
2. K. Iwata, B. Hasegawa, J. Heanue, P. Bennet, K. Shah, C. Boles, B. Boser. "CdZnTe detector for combined x-ray CT and SPECT" Nuclear Instruments & Methods in Physics Research A 422(1999) 740-744, Elsevier Science B.V.

KEYWORDS: Total Body Scan, Multi-Modal Scanning, Casualty Triage, Battlefield Imaging, Imaging Detector.

SB031-007 TITLE: <u>Alternative Transducers for Handheld Automatic Speech Recognition in Military Environments</u>

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

OBJECTIVE: Evaluate the feasibility of and then prototype a noise robust transducer (noise canceling microphone, array, etc.) to support the DARPA Phraselator handheld automatic translation device. This alternative configuration must enhance multilingual automatic speech recognition (ASR) by overcoming noise and other environmental effects that hinder ASR accuracy in current state of the practice directional microphone systems. Note, this is a direct wartime support proposal; the Phraselator is currently deployed in Afghanistan and other areas providing real-time translation support for the military, support organizations, and non-government offices (NGO's).

DESCRIPTION: The DARPA Phraselator was developed under a previous SBIR and a rapid development program. The current system incorporates a cardioic microphone technology that while usable, is highly vulnerable to performance degradation in typical military noise environments forcing the user to place the microphone very close to their mouth. A feasibility study is needed to evaluate radically new transducer systems to replace the directional microphone system and to enhance performance by incorporating the latest technologies to increase the SNR (Signal-to-Noise-Ratio) and utterance understandability.

PHASE I: Prepare and execute a feasibility study to evaluate alternative methods and technologies for enhancing ASR on small platforms (specifically the Phraselator) for improved ASR performance in noise and field environments.

PHASE II: Design a functional prototype transducer system on a government furnished Phraselator. The prototype need not be militarily hardened, but should be useable in an outdoor or field environment for short demos to validate usability and performance. After the prototype passes field and usability demos, the transducer system prototype must be military hardened. Implementation of the design is required on at least 500 Phraselator units. The units will be field-tested and feedback may be obtained for further refinement. Iterative refinement will be continued as funding permits.

PHASE III DUAL USE APPLICATIONS: A Personal Digital Assistant (PDA) Phraselator would help doctors; firemen and policemen interact with people who speak foreign languages. We envision travel agents offering a

Phraselator to travelers visiting foreign countries. A Phraselator would also enable teachers to interact with foreign students.

REFERENCES:

1. "The Phraselator: Translation system put to the test on the front lines in Afghanistan," Washington Technology (Washington Post), by Rob Terry, www.washtech.com
2. www.phraselator.com
3. http://www.sarich.com/translator/DOW%20web%20brief%20Oct%2099/
4. http://www.wirelesssolutionsjournal.com/articles/issue2/ADS-Militarized_PDA-Story.pdf


KEYWORDS: Personal Digital Assistant (PDA), Automatic Speech Recognition (ASR), Machine Translation (MT), Microphone Arrays, Noise Canceling Technology, Multi-Modal Speech Recognition

SB031-008 TITLE: Cluster-Based Repositories and Analysis

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop prototype software and a hardware cluster to support effective information warehousing and analysis for combating terrorism and similar computation.

DESCRIPTION: Currently, commercial data warehousers provide massive databases and computing infrastructure for financial and market analysis using proprietary data representations, networked disk arrays, and supercomputers. It would be nice to be able to have the infrastructure of commercial data warehousers in the form of a freely re-distributable system for use in combating terrorism and for similar computation (the system design and software should be freely- or cheaply-distributable at least within the Government; commercial rights would be retained by the successful offeror). Three emerging elements make this possible: (1) DARPA's Genisys program is re-inventing database technology for simplicity and flexibility, while retaining the ability to execute analytical queries. (2) DARPA's Genoa II and Evidence Extraction and Link Discovery (EELD) programs are creating innovative new methods of semi-automated and automated analysis on massive terrorism data sets. (3) Low-cost cluster computing is maturing rapidly and will significantly increase the maximum size of databases, processing power, and inherent scalability available to intelligence analysts. With the right design, we will be able to deal with 10-100 terabyte data sets, have the flexibility to add more processing and storage at any time at low cost, and be able to easily translate algorithms and software for use with the parallel supercomputer sought.

PHASE I: Conduct one or more feasibility related experiments to determine if it is possible to duplicate the data mining performance of commercial data warehousers using parallel computing infrastructure based on clusters of low-cost workstations. Key characteristics include support for innovative data representations, ease of expansion, and ease of software integration.

PHASE II: Build a full-scale working prototype of the system described above and demonstrate its utility in information storage, data mining, link discovery, model execution, pattern recognition, and other analysis tasks associated with combating terrorism. Facilitate translation of existing algorithms and software in DARPA's Information Awareness programs.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in many commercial business data mining applications.

REFERENCES:

1. ftp://ftp.active-templates.net/SBIR-Info-Genisys-Genoa-EELD.zip


KEYWORDS: Cluster-Based, Information Storage, Data Mining, Link Discovery, Pattern Recognition, Algorithms, Software

SB031-009 TITLE: Modeling Asymmetric Threats to Critical Infrastructure

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop an effective and valid predictive model that will map targeting characteristics of existing asymmetric groups to support enhanced detection, assessment, and interdiction of potential U.S. targets.

DESCRIPTION: To date over 400 organizations are considered hostile to the United States and its allies. As a result, the United States strategy must increasingly focus on developing detection, assessment, and interdiction capability of the potential threat at the earliest possible time and with the greatest amount of detail regarding potential targets. Research advances in area of cognitive and behavioral modeling offer potential enhancement to the predictive capability of these terrorist threats. However, there still remain some significant challenges to mapping these threat notices and warning to critical U.S. infrastructure at a confidence level that would support adjusting our security posture. Technology shortcomings include modeling of behavior moderators (ideology, cultural values, personality, etc), organizational dynamics and adaptive learning. In an effort to meet the objective of this SBIR, research may draw upon existing models, architectures, and techniques or create new ones. However, the approach should yield a significantly enhanced predictive capability in the following areas: automated mapping of threat attributes and capability to potential targets and assessment of the potential target's vulnerability.

PHASE I: Feasibility study to conceptualize and describe predictive modeling techniques based on behavioral and scientific modeling strategies and methodologies. Include a clear description of the metrics to be used to demonstrate the reliability and validity of the proposed model. The study shall indicate how the model will be generalizable across the wide spectrum of U.S. infrastructure deemed to be critical.

PHASE II: Develop and apply an implementation of the proposed model. The model will be based on relevant historical data and will be capable of identifying key variables that have adverse effects on national critical infrastructure vulnerability. Second, the model will be capable of projecting vulnerabilities from an asymmetric warfare perspective, as well as generating prevention and intervention scenarios. The implementation must include complete documentation to allow for direct replication of methods and results across a variety of threats.

PHASE III DUAL USE APPLICATIONS: The development of predictive modeling algorithms and technologies will have a very strong commercial potential with applications such as law enforcement (security agencies such as FBI, DEA, Secret Service), municipal planning, emergency management response (FEMA), international corporations, and non-government organizations (Red Cross). The generation of probable prevention and intervention scenarios would be useful in the event that asymmetric threats are realized. A valid model will present multiple opportunities for commercial applications. Such applications would provide means by which countermeasures to identified threats could be developed and implemented to decrease the probability of asymmetric threat. The model and prevention/intervention scenario generation would have utility from both corporate and government proactive perspectives.

KEYWORDS: Predictive Modeling, Human Behavior Representation, Asymmetric Warfare, Threat Assessment

SB031-010 TITLE: Wireless Near-Infrared Devices for Neural Monitoring in Operational Environments

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace, Human Systems

ACQUISITION PROGRAM:

OBJECTIVE: Develop wireless functional near-infrared devices capable of measuring neural and vascular signals from the human brain, with the goal of deployment in operational environments.

DESCRIPTION: In the past decade, advances have been made in the development of portable devices that have the potential to measure neural activity in operational environments. Understanding the functioning of the human brain in these operational settings is critical to achieving the DoD's goals of increased human performance in stressful conditions with simultaneous reduction in operator errors. Measurements of real time brain functioning will require simultaneous measurements of both the spatial and temporal components of neuronal and cognitive activity. The most significant advancements have come in the field of optical imaging, specifically the use of near infrared imaging as applied to biological tissues. These imaging devices use a non-invasive low power light, emitted by laser diodes or light emitting diode's (LED's) (700-1000nm range) and photomultiplier tubes or charge coupled devices (CCD) cameras to capture the biological events occurring in the human brain. These devices permit the spatial localization and measurement of vascular changes in biological tissues related to the change in blood oxygenation in specific volumes of tissue. This technique is known as the slow or near infrared spectroscopy (NIRS) signal, and occurs on the order of seconds. These measurements are of particular interest when applied to neural (brain) tissue, since changes in hemodynamics are thought to be related to neuronal activity and cognitive processing. A second, and potentially even more powerful measurement using near infrared devices, is the event related optical signal (EROS). This signal results directly from local changes in volume and ion concentrations that occur following the firing of neuronal action potentials. This EROS signal is fast, on the order of milliseconds, and corresponds well to other temporal measures of neuronal activity like event related potentials (ERP's). Together the NIRS and EROS signals have the greatest potential to give an integrated picture of brain activity, both spatial and temporal, from the same volume of tissue. The simultaneous recording of this type of data is essential for real time understanding of cognitive processing in any military environment. This topic seeks to further the development and ruggedization of this technology for its eventual deployment into operational environments. Near infrared devices that incorporate both the NIRS and EROS signal will be developed, tested and correlated with existing functional brain imaging data. Further phases will sponsor the development of prototype wireless devices, with concurrent testing in operational settings. And, since the NIR technology has physical compatibility with existing brain monitoring technologies, like electroencephalography (EEG) and event related potentials (ERPs), the final phase will also sponsor the integration of EEG/ERP with the NIR monitoring device.

PHASE I: Conduct exploratory study and preliminary testing of near infrared devices that can measure both the near infrared spectroscopy (NIRS) and event related optical (EROS) signals to determine the feasibility of wireless device development. Correlation of data collected with existing spatial and temporal functional data.

PHASE II: Design and develop a prototype wireless near infrared device for measuring the NIRS and EROS signals. Testing of device in an operationally relevant environment, with varying stress conditions.

PHASE III DUAL USE APPLICATIONS: The development of wireless NIR devices has applications in both military and commercial settings. Wireless NIR devices will have applications in military training, error detection and prevention, as well as monitoring of operations under stress. The NIR devices will find use in medical settings, as well as commercial instruction and training development.

REFERENCES:
1. Gratton, G. and Fabiani, M. Shedding light on brain function: the event related optical signal. Trends in Cognitive Sciences Vol. 5 No. 8 Aug 2001 357-363.
2. Chance, B, Anday, E, et. al, A novel method for fast imaging of brain function noninvasively with light Optics Express, May 11, 1998, vol. 2, No. 10.

KEYWORDS: Functional Near Infrared, fNIR, Event Related Optical Signal, EROS, Near Infrared Spectroscopy, NIRS, Hemodynamics, Wireless

SB031-011 TITLE: Personnel Monitoring for Assessment and Management of Cognitive Workload

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop an integrated, user centered cognition monitor with the capacity to measure the cognitive workload of the user, as well as levels of autonomic arousal and stress.

DESCRIPTION: The DoD faces a significant challenge in the 21st century. The reduction in the number of military personnel continues, while there is increased demand on each individual and team to achieve more. This challenge is only increased in today's complex operational environments, where multiple tasks compete for the operator's attention. In these complex environments it is crucial to know, understand, and be able to evaluate the workload and stress levels of military operators. If supervisors had the ability to quickly assess a soldier's current workload and fitness for upcoming tasks, work could be delegated more quickly to the personnel most available and mentally equipped to carry out the mission. We now have a multitude of tools at our disposal for measuring the cognitive and physiological status of military operators- these include eye tracking devices, pupillary reflex monitors, electroencephalography, event related potentials, and functional near infrared devices- as well as more traditional monitors of physiological status such as temperature, galvanic skin response, heart rate, blood pressure, and electromyograms. These measurements, taken together or in specific combinations, can provide as yet untapped information about operators that will allow for rapid assessment of fitness for duty and cognitive status. Additionally these methods of measurement are non-invasive and should provide minimal interference with performance of day-to-day tasks. This topic seeks to develop a suite of measurements that would be incorporated into a "monitoring workstation" that could be applied to a variety of operational settings. Proposers to this topic should seek to incorporate three or more measurement techniques, at least one cognitive and one stress related that could be used in both a command center and office environment to monitor individual cognitive workload and stress. The technology should not be application specific. Calibration tasks or applications are appropriate if needed. The initial phase will focus on the conceptual architecture and framework development, as well as research to determine the technical merit of this type of monitoring device. Further phases will focus on the development of prototype devices based on the architecture and framework investigated in the initial phases as well as development of algorithms for analysis of device output, to be used for personnel evaluation and assessment at the supervisory level.

PHASE I: Study a conceptual architecture and framework for the user centered cognitive monitor, and experimental research to determine the feasibility of a combined sensor and status-monitoring device. At least three different measures should be employed, with a minimum of one measuring cognitive workload, and one measuring stress/autonomic arousal related responses.

PHASE II: Development and testing of the Phase 1 conceptual architecture and framework, and implementation of a "proof-of-principle" demonstration of the combined sensors and status monitoring capability using existing measurement devices. Testing of the "monitoring workstation" in operationally relevant environments, with integrated and simultaneous recordings/outputs from all measurement devices.

PHASE III DUAL USE APPLICATIONS: The development of a personnel monitor for cognitive workload has applications in both military and commercial settings. These types of integrated monitors will find use in military training, error prevention, determining fitness for duty, as well as monitoring of operations under stress. Numerous commercial opportunities exist for this technology in the field of education, training, and monitoring of highly stressful work environments (e.g. nuclear power plant operation).

REFERENCES:
1. Pleydell-Pearce C.W. (1994) DC potential correlates of attention and cognitive load. Cognitive Neuropsychology 11 (2) 149-166.
2. Backs, R. W., Walrath, L. C. (1992). Eye movement and pupillary response indices of mental workload during visual search of symbolic displays. Applied Ergonomics 23, pp. 243-254.

KEYWORDS: Cognitive Workload, Stress Monitoring, Physiological Monitoring, Operational Environments, Fitness for Duty

SB031-012 TITLE: <u>Next-Generation, Unifying Architecture for Intelligent Agents</u>

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Create a new architecture for intelligent agent systems that unifies the strengths of existing architectures for building agents and cognitive models.

DESCRIPTION: There exist a variety of computational architectures for developing intelligent agents and human behavior models. Each architecture is unique to some degree, and has its strengths and weaknesses. However, there is also a great deal in common between the leading architectures. There is a need to exploit common features and combine unique strengths to build a new architecture that can powerfully represent human behavior, efficiently implement intelligent agents, and easily support user-friendly development and application. The resulting architecture should show improvements over existing architectures in terms of efficiency, usability, and ease of learning and engineering. Software architectures for intelligent agents and human behavior models are currently sophisticated enough to provide competent behavior for complex, interactive Intelligent Synthetic Forces (ISFs). There remain a number of potential improvements to these systems. Along one dimension, there is a need to develop new architectures that combine the variety of strengths currently provided by specialized systems. Another requirement is to increase general access to potential ISF developers, by improving the ease of use and deployment of intelligent agent architectures.

PHASE I: Analyze strengths and weaknesses of current leading architectures for intelligent agents and human behavior models. Develop a comparative framework to identify common and unique strengths and weaknesses. Use framework to design a new architecture.

PHASE II: Implement the new architecture and demonstrate its advantages with a representative sample of agent and human behavioral representation (HBR) applications. Implement development tools within the new architecture and demonstrate the architecture on a variety of real applications requiring intelligent agents and applied cognitive models.

PHASE III DUAL USE APPLICATIONS: Intelligent agents and applied cognitive models are becoming increasingly pervasive in modern computing. Powerful new architectures for such systems will enable rapid development of increasingly usable systems in both the military and commercial sectors. Military applications include improved modeling and simulation for training and war gaming. In the commercial sector these technologies and models will enable development of advanced cognitively based computational systems used in intelligent computing, modeling and simulation, and virtual reality development.

REFERENCES:
1. Pew, R.W., and Mavor, A.S., eds. (1998). Modeling Human and Organizational Behavior: Application to Military Simulations. Washington, DC: National Academy Press.

KEYWORDS: Intelligent Agents, Cognitive Architectures, Human Behavior Models.

SB031-013 TITLE: <u>Distributed Tracking with Networked, Dynamically Relocatable Sensors</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop ground-target tracking techniques and algorithms that could be employed by a distributed network of dynamically relocatable radars and other sensors.

DESCRIPTION: Technologies such as DARPA's Organic Air Vehicles (OAVs) are able to carry small radars, cameras and other surveillance sensors. (Information on OAVs can be obtained on the DARPA/TTO website.) OAVs are able to hover, perch or fly at speeds as high as 50 m/sec. OAVs support the optimal positioning of on-board sensors to provide persistent coverage of a given area, or they can be dynamically repositioned to allow the on-board sensors to maintain surveillance on critical moving ground targets. Optimal siting and dynamical relocation of the OAV platforms will allow a network of relatively short range, low cost sensors to provide high quality tracking performance over a large and dynamically varying battle space. To obtain the maximum benefit from sensors carried on multiple OAVs, tracking techniques and algorithms must be developed that continually: 1) reallocate the network's sensor resources, 2) reposition the OAVs to maintain favorable imaging target geometries and avoid line-of-sight blockage by terrain, foliage and/or cultural features, and 3) determine when multiple sensors can view a target to achieve enhanced tracking accuracy through multi-lateration techniques. For example, a sensor might be positioned to look down tree-lined roads or urban streets to minimize line-of-sight blockage when tracking critical targets. Also, two radars might image a target from significantly different angles to overcome the limitation in estimating the azimuth angle caused by broad antenna beam widths, while two passive sensors would be able to determine the range to a target. However there are constraints in repositioning the sensors, including fuel consumption rate and degradation or complete loss of sensor performance when an OAV is in motion. Also, if an OAV is perched to conserve fuel, sensor performance may be degraded by line-of-sight blockage due to obstacles or terrain undulations, by radar multipath, etc.

PHASE I: Develop a flexible tracker concept (algorithms and rules) that can ac-commodate a variable number of (possibly) heterogeneous sensors, and a broad range of sensor capabilities, target densities and surveillance area requirements. Specify the out-puts required from the various sensor types. Describe how databases, sensor data, etc. would be used to optimize sensor siting and enhance tracker performance. Describe the use of multi-lateration to enhance target position accuracy in the tracker. Describe the impact of uncertainty in the sensor locations on the tracking performance.

PHASE II: Implement the tracker in modular software so that it can be evaluated in either an event-driven simulation or in a non-real time hardware demonstration. Propose a prototype demonstration that will quantify the benefits of distributed tracking using networked relocatable sensors.

PHASE III DUAL USE APPLICATIONS: The techniques and algorithms developed un-der this SBIR would be applicable to evolving surveillance systems used by organizations such as the Army's Future Combat Systems and the Homeland Defense Organization, as well as by law enforcement agencies.

REFERENCES:
1. Tenny, R. R. and N. R. Sandell, "Detection with Distributed Sensors," IEEE Transactions on Aerospace and Electronic Systems, Volume AES-17, Number 4, July 1981.
2. Zhang, Ying, Henry Leung, Titus K. Lo, and John Litva, "Distributed multisensor multitarget tracking algorithm," Proceedings of the SPIE Vol. 2484, (Signal Processing, Sensor Fusion, and Target Recognition IV,) July 1995.
3. Cheng, Hongwei; Zhongkang Sun, Qi Liu, and Yongguang Chen, "Small-target tracking technique with data fusion of distributed sensor net," Proceeding of the SPIE Vol. 3163, (Signal and Data Processing of Small Targets), October 1997.

KEYWORDS: Network Tracker, Organic Air Vehicle, OAV.

SB031-014 TITLE: Novel Sensors and Signal Processing for Detecting and Classifying Combatants Operating in Urbanized Terrain

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop a suite of sensors and sensor systems that can perform Reconnaissance, Surveillance and Target Acquisition (RSTA) against mounted and dismounted adversarial forces, regular and irregular, operating in urbanized terrain.

DESCRIPTION: Friendly ground forces operating or fighting in urbanized terrain are subjected to threats from mounted and dismounted combatants who operate in a background wherein many non-combatants may be hostile, non-hostile or mixed and may provide active or passive support. The physical environment is characterized by very limited line-of-sight conditions, extensive multipath propagation of audio, acoustic, seismic and radio frequency propagation and a wide variety of noise sources. U.S. forces must be capable of operating in urbanized terrain, carrying out a variety of missions ranging from relatively docile peace keeping efforts to intensive, close-in fighting against a fortified force. Restrictive rules of engagement require very precise identification of human, vehicle and facility targets before they may be engaged or otherwise attacked. Sensors concepts are needed that can detect, recognize/classify, locate and track human, vehicle and facility targets operating in urbanized terrain in fog, haze, dust, rain, day and night. Sensors concepts have been investigated for this application to include day/night video (omni and point/pan/zoom), video object detection and tracking, acoustic and seismic arrays for target detection, recognition and tracking, through-the-wall radar to map 3-D human activity in rooms, effluent detectors, augmented aural capabilities to detect foreign speakers, etc. DARPA believes previously unexploited sensor techniques, signal processing and target phenomena currently exist that could be applied to the urban sensing problem. These concepts include but are not limited to novel radar and ladar devices (ultra wideband impulse radars, and floodlight illuminated ladar), devices to detect anomalies in background noise levels such as audio background or electro-magnetic fields, human effluent detectors, and so forth. Various sensor platforms are under development, which can be applied to urban RSTA operations such as aerial and land robots. The aerial robots include rotorcraft such as the DARPA Organic Air Vehicle and fixed wing micro aerial vehicles (www.darpa.mil, Tactical Technology Office, Unmanned Systems Programs). Rotorcraft have the potential to perch on building tops, towers, steeples, minarets and possibly fly into buildings through window openings. The objective of this topic is to challenge industry and academia to develop a next generation of novel urban sensors, sensor applications, sensor systems and sensor signal processing tools for RSTA operations against mounted and dismounted forces operating in urbanized terrain. Prospective developers should conduct a feasibility analysis of a specific concept. The study may deal with one aspect of the problem (a component technology) such as object classification or the entire problem (a system technology). A successful offering must include a discussion and solution to false alarm mitigation, and credible robustness in the cluttered urban environment. A successful offering must include a discussion of the concept of operations, and a credible analysis of the value-added compared to existing solutions.

PHASE I: The team will evaluate the feasibility of their proposed concept using any combination of techniques such as analytical modeling and simulation, or breadboard laboratory experiments using available hardware and software. The evaluation should clearly show that the concept is capable of detecting, recognizing/classifying, locating or tracking the targets of interest.

PHASE II: The team will conduct a proof-of-principle by developing a brass board sensor system and demonstrating its operation during a set of field experiments against live targets in a real environment.

PHASE III DUAL USE APPLICATIONS: The sensors and sensor concepts developed under this SBIR would be applicable to evolving surveillance systems used by organizations such as the Homeland Defense Organization, Transportation Security Agency and law enforcement agencies.

KEYWORDS: Sensors, Signal Processing, Target Recognition, Reconnaissance, Surveillance Acquisition, Target Acquisition.

SB031-015 TITLE: Motion Based Video ATR

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop robust automatic target recognition technology (ATR) for video sensors that can detect, segment, classify, and identify targets on the move, such as tanks, mobile missile launchers, armored personnel carriers, and other combat vehicles. Specifically, exploit the spatio-temporal information inherent in video data that results from multiple looks at a target available from a sequence of video frames obtained as the target moves.

DESCRIPTION: The war in Afghanistan demonstrated the key role video sensors on unmanned air vehicles (UAVs) could play in obtaining real-time intelligence and targeting data on mobile and moving targets. In fact, video data is the single largest source of intelligence information, and the acquisition of video data continues to grow at an exponential rate. Further, the Rules of Engagement under which our forces operate require visual confirmation of target ID, and there is simply too much video data being collected to expect our warfighters to review it all. Methods to automatically recognize items of military equipment are required to magnify the warfighter's ability to find and identify targets using video sensors, particularly in urban environments. Targets on the move can be detected reliably by GMTI (ground moving-target indicator) radar, but they cannot be automatically recognized with a high degree of probability. In contrast, electro-optical (EO) and infrared (IR) motion imagery has the potential to provide positive target recognition, but despite several decades of research on video ATR, it has proven to be a very difficult problem to solve with enough reliability to become operationally deployed. Much of the research on EO and IR target recognition has focused on spatial information such as 2-D shape measures and geometrical arrangement of features in single frames of a video sequence. While sophisticated 3-D target signature models have been developed, they cannot be fully exploited by such approaches. Even though much of the information from a video sensor is redundant frame-to-frame, there is nevertheless a rich source of additional information on target shape, motion characteristics, and appearance available by examining the changes that do occur over time through multiple video frames as a result of the target's and/or sensor's motions. The focus of this effort is to develop robust video ATR algorithms that exploit this motion information to more reliably identify targets on the move. Simply applying ATR techniques developed for still-frame imagery to successive frames from motion imagery is not acceptable – we seek solutions that specifically exploit the redundancy, continuity, and multiple-perspectives inherent with video. Solutions should consider the effects of diverse pose, illumination, shadows, and related phenomena. For the purpose of maximizing effort toward developing robust solutions to video ATR, it is acceptable to assume a stationary camera mounted near ground level. This sensor would be positioned so as to be able to monitor traffic on a thoroughfare, and the video ATR system would be expected to signal whenever a vehicle within its target set appeared within its field of view. While the recognition of military equipment is our ultimate goal, it is acceptable to use civilian vehicles as targets and confuse traffic, so as to maximize the volume of experimentation that can be performed. Real-time solutions will ultimately be required, but robust recognition performance in terms of high Prob(identification) and low Prob(false identification) is the explicit goal of this project.

PHASE I: Assess the feasibility and potential performance of a motion-based video ATR capability and propose a development effort to build and test a working software prototype. Describe algorithmic approaches to solve frame-to-frame or frame-to-scene model registration, target segmentation, target tracking, and target recognition problems that make the most of motion information inherent in multiple video frames.

PHASE II: Develop, demonstrate, and evaluate a prototype software system capable of robust recognition of vehicles in video imagery.

PHASE III DUAL USE APPLICATIONS: Reliable, robust video ATR algorithms and software would have significant benefit to both defense and commercial video monitoring and surveillance applications in force protection, physical infrastructure security, counter-terrorism, law enforcement, and special operations. Commercial video surveillance and monitoring is one of the fastest growing commercial technology sectors today, but its utility is limited by the cost and availability of trained security personnel to watch video feeds. Automated object recognition would provide a huge boost to this market.

KEYWORDS: Video, Automatic Target Recognition, Precision Identification, Object Classification, Motion Imagery Processing.

SB031-016 TITLE: Design of Nano-Photonics Devices and Systems

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

OBJECTIVE: Develop and demonstrate novel and robust analysis and iterative design methods amenable to micro- and nano-photonics devices. The design methods should be incorporated in software capable of designing three-dimensional devices such as photonic band gaps and integrated optical devices using common desktop computer resources.

DESCRIPTION: Modern micro- and nano-fabrication methods have made it possible to fabricate photonic devices on an unprecedented small scale. From this capability a variety of new devices such as photonic band gaps and micro-photonic resonators have become widely used. One impediment that has slowed the development of new micro- and nano-photonic devices has been the lack of adequate computer software for analysis and iterative design. To numerically analyze and design such devices requires the use of rigorous three-dimensional electromagnetic algorithms. However, conventional methods are too computationally restrictive to solve such large three-dimensional problems in a time frame that would prohibit iterative design. As a result there is a present and growing need for design codes dedicated to micro- and nano-photonic devices. Thus, the objective of this topic is to promote the development of new rigorous numerical techniques targeted at the analysis and iterative design of micro- and nano-photonic devices.

PHASE I: Demonstrate rigorous algorithms for design of nanophotonic devices and show feasibility of approach by comparison of calculation with measured performance of nanophotonics devices.

PHASE II: Incorporate optimized electromagnet analysis algorithms into a software package and provide a rigorous analysis of their range of applicability in terms of device dimension, complexity etc. Demonstrate limitations and robustness through a series of comparisons with measurements of fabricated devices and circuits.

PHASE III DUAL USE APPLICATIONS: Photonics is key to numerous DoD systems. Integration of photonics and electronics into Microsystems requires design and analysis tools which currently only exist in a very specialized form. In particular ‘user friendly’ tools to speed the design and integration of nanophotonic devices and circuits do not exist. DoD will benefit by having such design tooling for the design of photonic systems and Microsystems. Commercial applications include the design of efficient optical routers, modulators, channel drop filters and other components and systems used in photonic-based communication.

KEYWORDS: Photonics, Photonic Crystals, Optical Bandgaps, Nanophotonics

SB031-017 TITLE: <u>Miniaturized Scanning Electron Microscope</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop miniaturized (few cm2 footprint) Scanning Electron Microscope (miniSEM) to perform microscopy in a compact package with low consumed power.

DESCRIPTION: Current SEMs offer resolution (sub nanometer) far beyond that achievable by optical microscopes. However, they have a footprint of the order of 100 sq ft, require a dedicated facility for installation and are extremely expensive to manufacture. Using advanced silicon micromachining techniques; it is possible to miniaturize the electron optic column in a SEM and operate at far low voltages and consumed power while maintaining the high-resolution capabilities of the SEM. This makes the idea of a tabletop SEM that is versatile and can be used to inspect objects that are currently extremely inconvenient to examine in conventional SEMs. These include non-destructive in-situ measurements of living biological systems and inspecting parts of large objects that cannot be inserted into a conventional SEM. While proven prototypes have been demonstrated in various R&D labs1, these designs need to be re-designed and re-engineered for use as SEMs, which rely on batch processing technologies for, manufacture which will lead to order of magnitude reduction in cost. Opportunities also exist for operation in an electron-optic regime, which is inaccessible with current technology. These include very low voltage (<1 kV) with relatively high currents (~1 nA) while maintaining high imaging resolution. This leads to a flexibility of operation allowing inspection of highly insulating materials and materials in-vivo, which present significant challenges to conventional SEMs.

PHASE I: Perform a design study of a high resolution (~10 nm) miniSEM, which relies on cost effective manufacturing technologies and components. Determine the feasibility of developing a prototype turnkey miniSEM prototype.

PHASE II: Develop and demonstrate a prototype ~10 nm resolution miniSEM with a column footprint of a few sq cm that can be operated in a tabletop mode and relies on batch processing techniques. Provide an analysis of potential opportunities for a product based on the developed prototype.

PHASE III DUAL USE APPLICATIONS: The miniSEM will enable the inspection of many key military and civilian high-performance structures, devices and systems which are currently unable to be inspected with nanometer resolution. These include dual use systems such as parts of aircraft, highly insulating materials and biological materials in-vivo.

REFERENCE:
1. Several papers describing micro Columns developed for e-beam lithography applications can be found in the Journal of Vacuum Science of Technology over the last 5 years.

KEYWORDS: Microscopy, Electron Microscopy, Electronics, Inspection

SB031-018 TITLE: Noise Tolerant Nanoelectronics

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics, Battlespace, Space Platforms

OBJECTIVE: Identify, characterize, and overcome the susceptibility of nanoelectronic devices to noise upset from radiation in the space environment.

DESCRIPTION: Radiation hardness has been a critical issue in the space electronics community for many years. Massive effort has gone into understanding and overcoming radiation effects. Both process and design methods have been explored. While much is known and much has been accomplished in this area, entering the nanoelectronics (< 100 nm feature sizes) era, there are many unknowns and radiation hardness is no longer just a space electronics issue. The commercial integrated circuit (IC) industry has already observed an increase in radiation effects at sea level, as they have scaled into the submicron regime. Additionally, because nanoelectronic devices have operating voltages of less than 1 V and thresholds close to 0 V, devices/circuits with such operational parameters can be highly sensitive to noise from multiple sources besides radiation particles. Effects such as electromagnetic interference (EMI) will become even more important, since nanoelectronics is anticipated to be the technology vehicle for radio frequency (RF)/analog mixed signal circuits. This creates the opportunity for on-chip EMI from the RF block to affect the digital circuits and for the digital switching noise to couple through the substrate into the analog functions. As the basic purpose of an analog device is to sense small changes in a signal, the nanoelectronics environment will provide many opportunities for small changes to occur in the signal to be monitored. Further, some of the key materials that have been used in microelectronic circuits for years and are reasonably well understood may well be replaced in the next few years. While this is necessary in order to achieve the required device characteristics, little is known about the behavior of these materials (and the devices/circuits in which they must function) in either a radiation or multiple-noise-source environment. A comprehensive effort is needed to identify, characterize, and overcome nanoelectronic device susceptibility to noise upset. This will address issues such as those created by new materials, operation of the devices at low operating voltages, integration of multiple device types onto a single chip, narrow noise immunity margins, use of thin substrates to reduce system volume and aid heat transfer, as well as effects created by different noise sources. Subsequent work will build on the understanding gained to develop methods for mitigating the noise effects. Where appropriate, existing "rad hard" will be evaluated as means to either physically "harden" the circuits or to enable them to detect and correct noise upset effects. An important aspect of the program will be to identify underlying mechanisms at the device level that make it susceptible to noise upset. This would allow exploring generic "robust" devices and methods, rather than developing multiple solutions for multiple noise sources on an ad hoc basis. New approaches such as noise immune/tolerant macrocells that are placed in critical paths (at the expense of area, power and delay) to ensure proper functioning of the functional block will also be explored. The development of Noise Tolerant Nanoelectronics is essential if the military is to achieve the full benefit of device scaling to provide high performance computation and communications integrated circuits.

PHASE I: Identify and characterize nanoelectronic device susceptibility to noise upset by radiation in the space environment and identify means and strategies to overcome this susceptibility. Include issues such as those described above.

PHASE II: Develop methods identified and characterized in Phase I to mitigate the noise effects and render nanoelectronic devices "rad hard" in an orbiting space environment. Demonstrate proof-of-concept hardware to physically harden circuits containing nanoelectronic devices or a methodology for detecting and correcting such noise upset effects.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in the commercial market for space-based sensors and communications systems employing state-of-the-art nanoelectronic circuits, including optoelectronic devices.

REFERENCE:
1. P.V. Dressendorfer, T. P. Ma, "Ionizing Radiation Effects in Mos Devices and Circuits", Wiley-Interscience; ISBN: 047184893X (1989).

KEYWORDS: Nanoelectonics, Nanoelectronic Devices and Circuits, Noise Tolerant, Noise Mitigation

SB031-019 TITLE: Distributed Electronics

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics, Battlespace

OBJECTIVE: Identify and develop innovative technology using distributed electronics and/or flexible substrates and having the potential to increase the utility of electronic subsystems while offering significant cost, complexity and weight reductions over the existing systems.

DESCRIPTION: Many of the most demanding military electronics applications are space-, weight-, and power- (SWAP) constrained and they must be kept affordable if the overall system is to be viable. Novel technologies that address both the SWAP and cost factors of future electronics are a key element in maintaining the dominant position of our war fighters. This program will develop several technologies with the potential for increasing the utility of electronic subsystems while at the same time offering significant cost reductions over the existing paradigm. Organic and polysilicon transistor technology has been shown to be feasible on flexible and/or conformable substrates. These devices can be fabricated by techniques based on printing technology rather than the costly lithographic methods used today. Such a capability not only could result in lower cost electronics, but the ability to print over wide areas on flexible substrates would provide a distributed electronics capability. This would allow the electronics for diagnostic, control and sensor applications to cover the surface of active systems (e.g., wings) or inert, structural elements to conserve space and/or weight (in unmanned aerial vehicles (UAVs). Further, with a flexible substrate, the electronics package might be folded or rolled up for storage when not operational. By reducing cost and complexity of electronics and using a flexible substrate, it becomes easier to distribute the overall electronics package over an entire structure or area. To achieve these objectives a number of technical challenges must be overcome. If existing integrated circuit (IC) methods are to be replaced in significant DoD electronics applications (as is the case for display technologies), then the materials, processes, and devices available with organic and polycrystalline materials must be significantly improved. A combination of cost reduction and performance enhancements must occur in classic "disruptive technology" fashion. Further, assessments of application requirements vs device/circuit capability must be conducted to provide technology drivers to assess the feasibility of various concepts. Architectural alternatives must also be examined to take advantage of low-cost transistors and to achieve the desired functionality via massive parallelism.

PHASE I: Conduct feasibility study on an innovative technology, using distributed electronics and/or flexible/conformable substrates with potential for significantly increasing the utility of electronic subsystems and significantly reducing cost, complexity and weight over the existing systems. Model or otherwise analyze the identified technology to demonstrate the feasibility of the approach.

PHASE II: Develop the innovative technology identified and characterized in Phase I and demonstrate, using a proof-of-concept hardware system, significant increases in electronic subsystem utility and reductions and cost, complexity and weight, using the distributed electronics and/or flexible/conformable substrates demonstrated by modeling or analysis in Phase I.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in the commercial market for embedded processors and for mobile sensors and communications systems which are space, weight, and power (SWAP) constrained.

REFERENCES:
1. G. Horowitz, "Physics of Organic FETs in Conjugated Polymers", Wiley-VCH (1999).
2. B. Chalamala, "Flat Panel displays and Sensors: Principles, Materials, and Processes", Materials Research Society Proceedings # 558 (2000).

KEYWORDS: Distributed Electronics; Flexible Substrates; Conformable Substrates; Space-, Weight- and Power-Constrained Systems or Subsystems

SB031-020 TITLE: Lithographically Scribed Planar Holographic Devices

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

OBJECTIVE: Develop flexible spectral filtering devices based on holographic diffractive structures in planar optical waveguides for applications including high performance spectral sensors for target discrimination, optical encoders/decoders for secure code-based communications, and multiplexers/demultiplexers for robust wavelength-division-multiplexed high-bandwidth optical communication links.

DESCRIPTION: The nanostructuring of photonic materials offers unique new pathways to the realization of powerful optical device functions. This is especially true in instances where nanostructuring can be implemented entirely or partially using the standard lithographic tools employed in semiconductor integrated circuit manufacturing. Planar waveguide structures appear to hold unique promise as a platform for the fusion of advanced optical design concepts and semiconductor nanofabrication techniques. On the forefront of this opportunity area is the development of robust, high performance, and highly manufacturable devices based on the lithographic writing of holograms within the core layer of fully two-dimensional planar waveguides. Devices based on lithographic holography may provide for small, highly robust, high resolution, and fully coherent spectral filtering. At the same time, holographic designs may provide for spatial wavefront control and routing of on-chip optical signals without utilization of limiting channel waveguides. The lithographic approach to holographic device fabrication eliminates the complex optical writing process normally associated with holography as well as the serious limitations imposed by the robustness and stability of photo recording materials. Lithographic holograms offer promise of extreme robustness through etch-based rendering in materials like silicon and silica. Lithographic mastering followed by embossing-based design transfer opens the opportunity to high performance devices of extremely low cost. Practical demonstrations of lithographically rendered holographic designs coupled with utilization in specific device and product contexts involving, for example, coherent spectral filtering, optical signal processing, optical correlation, and spatial beam routing functions are required to confirm the importance of the approach.

PHASE I: Evaluate the feasibility and competitiveness of lithographically scribed planar holographic devices as applied to coherent spectral filtering, optical signal processing, optical correlation, spatial beam routing, or other commercially viable application through simulation, modeling, and consideration of available fabrication methods.

PHASE II: Develop detailed designs for proposed lithographically scribed planar holographic devices. Fabricate, test, simulate, and refine proposed devices for high performance, reliability, and consistency. Confirm and optimize competitive advantage over existing products. Develop a reliable and consistent manufacturing approach. Develop robust packaging solutions. Create product-compatible, fully packaged, late-stage device prototypes. Develop a plan for commercialization.

PHASE III DUAL USE APPLICATIONS: It is anticipated that lithographically scribed planar holographic devices will find application in commercial and military communication systems as multiplexers, spectral signal conditioners/pulse shapers, and channel coders/decoders - especially where robustness, reliability, and low cost are prime considerations. Other product areas include high speed optical processing as required for example in optical packet decoding and in spectral target recognition.

REFERENCES:
1. “Planar holographic optical processing devices,” T. W. Mossberg, Opt. Lett. 26, 414 (2001).
2. “Apodized Surface-Corrugated Gratings With Varying Duty Cycles,” D. Wiesmann, C. David, R. Germann, D. Emi, and G. L. Bona, IEEE Phot. Tech. Lett. 12, 639 (2000).

KEYWORDS: Holography, Lithography, Optical Processing, Code-Multiplexing, Optical Communications, Spectral Sensing, Target Recognition

SB031-021 TITLE: Sea Glider Transport Vehicle

TECHNOLOGY AREAS: Ground/Sea Vehicles

OBJECTIVE: Design and develop an underwater vehicle that uses buoyancy control and vehicle lift to drag as the primary means of propulsion for the transport of equipment, supplies, sensors, weapons, and personnel in a silent and efficient manner.

DESCRIPTION: Soaring birds inspired man's first successful attempts at winged flight. It is well understood that gliding flight in the atmosphere can be achieved with the conversion of potential energy into work to offset vehicle drag. In addition, aircraft can gain energy from updrafts, currents, and winds that in turn can be used at work to offset drag. In a similar manner, sea mammals and fish are known to sometimes glide in water by trading potential energy into work against drag. In the case of an airplane, potential energy is in the form of altitude. A gliding airplane trades off altitude to propel itself forward. In the case of a sea mammal, the animal allows its buoyancy to decrease. This causes it to sink and glide forward. If we think of sea creatures as underwater flying vehicles they can inspire us to think of underwater gliding craft. Underwater gliders should be able to fly in the oceans just like airplanes fly in the atmosphere. In the same manner, sea gliders can convert potential energy by sinking into the deeps just like a gliding airplane gives up altitude to propel itself forward. A sea glider should be able to use the ocean's current, up flows and tides to gain energy for continued flight. But liquid flight has an advantage over atmospheric flight; a sea glider that has reached a great deep can reverse its buoyancy and glide upwards. A sea glider can glide both downwards and upwards to continue its glide indefinitely as long as it continues to cycle its buoyancy. The concept of sea gliders has been successfully demonstrated for long duration flight of oceanographic sensors. The project hopes to broaden the application of the mode of underwater propulsion to the transport of equipment, supplies, sensors, weapons, and personnel. Sea gliders hold the potential for efficient transport under water for long distances in a very quiet and passive manner. There are a number of both military and commercial applications that could benefit from this form of transportation.

PHASE I: Systems studies to identify requirements for potential applications and performance studies to size concepts and identify technology and design requirements. In this early phase a number of vehicle concepts will be described and at least one simple proof of concept model will be demonstrated.

PHASE II: A target application will be identified. A proof of concept model for this application will be designed and constructed for limited demonstration. This model need only be sized and constructed in a manner that provides a realistic demonstration that will justify future investment.

PHASE III DUAL USE APPLICATIONS: There are a number of military and commercial applications for this class of vehicle. In the military sector a sea glider transport would allow a submarine to deploy an unmanned aerial vehicle (UAV), a sensor platform, and personnel by launching a sea glider. A sea glide could travel a considerable distance from the submarine, silently, before it deploys its payload. By deploying a payload at great distances from the submarine, the unknown location or presence of the submarine's can be maintained. In the commercial sector, sea gliders can transport equipment and personnel to locations that have harsh surface conditions. The oceanographic community has already targeted sea gliders as an effective way to collect data over wide expanses of the oceans.

REFERENCES:
1. Graver, J., Liu, J., Woolsey, C., Leonard N. E., "Design and Analysis of an Underwater Vehicle for Controlled Gliding," In Proceedings of the 1998 Conference on Information Sciences and Systems, Princeton, NJ, March 1998, P. 801-806, http://www.princeton.edu/~naomi/ciss98.html

KEYWORDS: Submarine, Glider

SB031-022 TITLE: High Resolution Local Sea Surface Mapper

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop a sensor that can provide a detailed, real-time, high-resolution map of the wave field and its time variation, in the vicinity of a small vessel.

DESCRIPTION: The use of networked, unmanned vessels and sensor platforms will provide greatly enhanced capabilities to the future naval force operating in littoral environments. However, unmanned surface craft will not be practical until their survival in storms and heavy weather is assured. Increasing survivability through strengthening of a small vessel's structure, or building it to tolerate wave impact and immersion, has been shown to add mass, reduce payload fraction, and decrease maximum speed and range, all of which reduce mission effectiveness. The alternative is to increase survivability through intelligent sensing and control. There are various proposed approaches to implementing a control scheme for vessel survival steering. Among these approaches, some will require a detailed map of the waves and their motion all around the vessel, which has a very high update rate to enable the control system to react to storm phenomena such as heave, breaking waves, confused seas, etc. Such a sensor must be able to tolerate the marine environment, provide all-weather data in useful form to a control system, and be small and light enough to be carried by small craft. A successful sensor and control system will enable inexpensive commercial fiberglass craft to be fitted out for a variety of military missions in the littoral.

PHASE I: Determine the feasibility of a sea-mapping sensor capable of being mounted on a fifty-foot fiberglass ocean racing boat with adequate stability margin. Investigate the functionality of the design through computer simulation in all weather conditions. Analyze the environmental performance requirements for packaging the sensor. Investigate high-level software design requirements for the sensor and its outputs for use by a vessel adaptive control system.

PHASE II: Build a brassboard sea-mapping sensor protected for short-term exposure to the marine environment. Develop software necessary to display data of wave height and motion in real time. Conduct field-testing, and obtain satisfactory agreement between wave data developed by the sensor and in situ data collected by other instrumentation (video, wave gauges, etc.).

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used for oceanographic measurements, and will contribute significantly to enhanced safety of commercial shipping and fishing vessels. In addition to unmanned craft control, military applications for this sensor will also include safety and expanded operating envelopes for special operations craft and Coast Guard rescue craft.

REFERENCE:

1. Congressional Research Service, "Naval Transformation: Background and Issues for Congress," Order number RS20851, http://www.fas.org/man/crs/RS20851.pdf.

KEYWORDS: Unmanned Vessel, Sea Surface, Wave Sensor

SB031-023 TITLE: Short-Range Ultra-Low-Cost Anti-Submarine Sensors

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop sensor/communications packages that can sense the physical presence of a submerged submarine at very short range, and that can be manufactured cheaply enough to enable very high density seeding of anti-submarine barriers.

DESCRIPTION: Detecting and locating submarines is always difficult. It is even more difficult in relatively shallow water (depths of 20 to 200 meters), because of reverberations, short acoustic propagation distances, the presence of magnetic objects on the ocean bottom, and high shipping densities. For these reasons, the use of sophisticated passive acoustic detection and location technologies may not suffice to protect naval forces operating in a hostile littoral environment. The Naval Doctrine Command publication "Littoral Anti-Submarine Warfare Concept" states, "Littoral ASW [anti-submarine warfare] must incorporate search techniques, sensors and systems that exploit non-acoustic and active acoustic signals in addition to the passive acoustic signatures currently preferred in open-ocean ASW." Such detection means might include sensing the physical presence of a submarine (e.g., submarine breaks a string or wire, a magnet sticks to submarine, impact), or its near-field emissions (acoustic, magnetic, electromagnetic.) Such detection schemes are more feasible given the successful demonstration of many types of microelectromechanical (MEMS) sensors. However, because such techniques are likely to yield detections only at extremely short ranges, the sensors would have to be deployed in very high density for a good barrier (perhaps thousands per square mile). Cost and manufacturability are therefore key enablers of such sensors; no more than a few dollars per sensor would be acceptable in large quantities. For the same reason, the devices would also be able to incorporate only the most primitive processing and communication subsystems. Determining that a submarine had been "detected" and "located" would likely be a probabilistic determination based on the collective signature of a large, dense field of the sensors, rather than from the output of an individual sensor. To avoid damaging the marine ecosystem by deploying large numbers of objects, the sensors should be substantially biodegradable (avoiding, for example, the use of nylon monofilament line).

PHASE I: Develop conceptual designs of at least two complete ultra-low-cost, short range ASW sensor schemes using environmentally benign materials. Evaluate the functionality of the detection and communication features of the sensors, as well as their survivability in the marine environment. The conceptual design should include a communications and data processing unit for monitoring the sensors in the water. Also design an automated manufacturing process capable of producing one hundred thousand units per year. Perform a complete manufacturing process analysis including a detailed per-unit cost breakdown, in order to allow evaluation of the affordability of the devices.

PHASE II: Produce prototype sensor units using manual methods. Produce a brassboard monitor unit containing communications and processing equipment capable of monitoring a one thousand sensor ASW barrier. Provide sensors and monitor to the U.S. Navy for functional testing in a field environment. DARPA Mission/Core funds will pay the Navy for this testing. The small business will NOT be using their SBIR Contract funds to pay the Navy for these tests.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used for marine biological and marine environmental sensing. In addition to the anti-submarine detection function, military applications may include monitoring shallow water zones for swimmer and small craft operations.

REFERENCE:
1. Littoral Anti-Submarine Warfare Concept, Naval Doctrine Command, 1 May 1998, http://www.fas.org/man/dod-101/sys/ship/docs/aswcncpt.htm.

KEYWORDS: Submarine, Sensor, Communications, Detection

SB031-024 TITLE: Rapid Design & Development of Behaviors for Autonomous Vehicles

TECHNOLOGY AREAS: Air Platform, Information Systems

OBJECTIVE: Develop methodology, language, and supporting tools to facilitate the rapid development of general, reusable behavior components for autonomous, unmanned vehicles (UV).

DESCRIPTION: In the future, battlespaces will be populated with autonomous vehicles that provide a rich array of tactical and strategic functions: everything from intelligence gathering and situation assessment to munitions delivery. These autonomous vehicles, or agents, will need to interact and coordinate with each other and with human systems. To date, most agents are designed and built from relatively low-level architectures, with little behavior knowledge directly transferable from one agent application to another. This problem is especially acute in robotic systems, where the hardware available for sensors and effectors drive higher-level behavior designs. This SBIR will develop a methodology (and tools to support the methodology) that will promote the development of general behavior components, which are then specialized for particular applications (e.g., both intelligence gathering and munitions delivery agents will need "communication modules," although the specifics of their communication may be quite different). An important constraint on the new methodology and tools is that they not be specific to any one agent architecture. Such generality requires an "agent behavior language" that can be used to specify agent behaviors independent of any particular agent system. The advantage of this approach is two-fold. First, it allows reusability across agent architectures: the same design could be re-used (and translators could be developed to automate most of the agent-architecture-specific code creation). Second, it creates a de facto application program interface (API) for interacting with lower level components (e.g., the avionics control system of an unmanned air vehicle). Thus, the language defines a distinct separation between the tactical decision-making components of the agent and its underlying control processes. Tools are critical because they enforce the methodology. The tools should support visual design principles and not require a user to have significant knowledge of the syntax of the underlying agent behavior language. This requirement helps move the behavior creation process into the hands of users rather than developers, allowing during-the-battle composition of very specific behaviors for a particular mission. Although there are numerous agent design tools available (e.g., [1], [2], [3], [4]), the existing tools are specific to a particular agent architecture. The goal here is to create behavior design tools for the unmanned vehicles domain, which can be used in conjunction with translators to provide implementations for many agent architectures.

PHASE I: Phase I activities will provide a study that proposes and evaluates different existing agent design methodologies and tools. The outcome of Phase I will be a proposal for a design methodology and supporting tool set that are appropriate for unmanned vehicles. Also in Phase I, a preliminary specification of the agent design language will be developed.

PHASE II: Phase II activities will result in the development of the agent design tools and a demonstration of design and fielding of a UV agent. The agent will be fielded in a real-time distributed simulation.

PHASE III: In the FAA automation of air traffic routing, airport runway and taxiway capacity, and weather forecasting are all being individually automated and information presented to the operators. These advanced agents could be used to roll up this information to optimize air traffic flow into and out of the airports and airspace.

REFERENCES:
1. Barber, K.S., DACAT: Designer's Agent Creation and Analysis Toolkit. 2000. http://www.lips.utexas.edu/UTAustin/AgentDesign/
2. Storey, M.-A.D., F.D. Fracchia, and H.A. Müller., Cognitive Design Elements to support the Construction of a Mental Model during Software Exploration. Journal of Software Systems, 1999.
3. Laird, J.E., Visual Soar. 2002. http://ai.eecs.umich.edu/soar/visualsoar/
4. Freed, M.A. and R.W. Remington. Making Human-Machine System Simulation a Practical Engineering Tool: An Apex Overview. in 2000 International Conference on Cognitive Modeling. 2000. Groningen, Netherlands.

KEYWORDS: Autonomous Vehicles, Unmanned Vehicles, Application Program Interface, Agent Behavior Language

SB031-025 TITLE: <u>Anti-Icing Technology for Unmanned Rotorcraft</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop lightweight, affordable technology for the detection and / or prevention of icing for unmanned rotorcraft applications.

DESCRIPTION: The military utility of unmanned platforms as a force multiplier has been demonstrated by the recent conflict in Afghanistan. Currently, operation of these systems is greatly restricted by weather restrictions in the area of operations. Much of Europe, former Soviet Union (FSU) countries and significant parts of other theaters of operation have extensive icing conditions for a significant portion of the year. The U.S. is investing heavily in the integration of unmanned aerial vehicles (UAVs) as part of the persistent Intelligence, Surveillance, and Reconnaissance (ISR) infrastructure. The ability to build an unmanned rotary wing vehicle, which is effective at low altitudes year round, is dependent on the ability to develop and demonstrate a technology to keep critical portions of the aircraft free of ice. The technology proposed must be lightweight, require reasonable amounts of power, and be compatible with modern manufacturing techniques and materials. The initial target application for this work will be DARPA Unmanned Rotorcraft systems. Approaches that are not currently used on military platforms are of primary interest.

PHASE I:  Define a technology approach to solving the anti-icing problem for unmanned rotorcraft.  Identify any enabling technologies needed to make this a practical device.  Identify the key performance characteristics of the proposed system.  Delineate the weather conditions over which the proposed technology will operate effectively.

PHASE II:  Develop a prototype system that will be tested in a Government owned Icing Tunnel.  DARPA will pay testing costs with mission/core funds, not the small businesses SBIR contract funds.  DARPA has no Icing Tunnel facilities, however, there are Icing Tunnels located within the Federal Government for use by contractors.  Design a system using these technologies with direct application to DARPA unmanned rotorcraft programs.

PHASE III DUAL USE APPLICATIONS:  This technology will have application to DoD and civilian rotorcraft systems.

KEYWORDS: Anti-icing; UAV; Icing; Rotorcraft